

CONTROL OF THE CORN EARWORM ON FORDHOOK
LIMA BEANS IN EASTERN VIRGINIA E.M.V.By LOYD W. BRANNON,¹ *assistant entomologist, Division of Truck Crop and Garden Insect Investigations, Bureau of Entomology and Plant Quarantine*

United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, in Cooperation with the Virginia Truck Experiment Station

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INTRODUCTION

The corn earworm (*Heliothis obsoleta* (F.)), a very destructive insect enemy of ear corn, frequently causes severe damage to the fall crop of Fordhook lima beans on the Eastern Shore of Virginia, attacking this crop after corn in the vicinity has dried out and is no longer attractive to the moths for egg deposition. In the fall of 1934 growers throughout this area asserted that from 20 to 30 percent of the bean pods were damaged by the insect, the injury necessitating hand culling of the damaged pods prior to marketing the crop. This procedure considerably increases the cost of marketing the crop, and there is, of course, in addition, the loss caused by the insect, as the culled pods are sold for about one-half the price of the uninjured pods. The fall crop of Fordhook lima beans in this locality, planted in the last part of July and harvested during the last part of October and first part of November, usually commands a fair price in the northern markets and is thus of considerable value to the growers of this area.

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Experiments were begun in 1935 to determine the relative effectiveness of various insecticides for control of this pest on Fordhook lima beans. The data presented in this circular include the results of experiments conducted from 1935 to 1938, inclusive.

FEEDING HABITS AND NATURE OF INJURY

Corn earworm damage to lima bean pods is caused by the feeding of the earworms on the pods. The moth, or adult, deposits its eggs on the bean foliage, the majority observed being laid on the upper surface of the leaf. After hatching, the worm begins to feed on the leaf upon which the egg is laid, later wandering about feeding on the leaves until about three-fourths of an inch in length before attacking the pods. It makes a round hole through the pod wall and often completely devours the contents of the pod (fig. 1). The holes vary

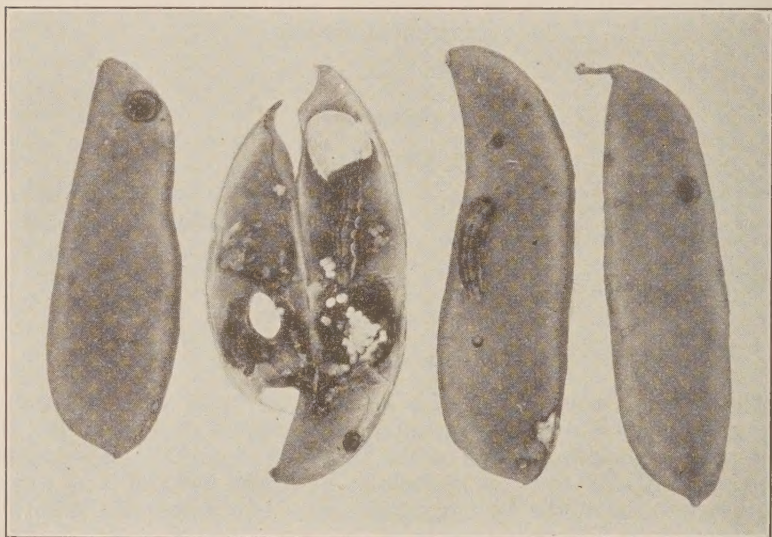


FIGURE 1.—Fordhook lima bean pods showing typical corn earworm injury. Note the round holes through the pod walls and the damage to the interior of the opened pod.

in size but normally range from a diameter of about one-fourth to one-half inch and may appear at any point on the surface of the pod. Frequently pods thus affected do not contain larvae, since several pods are often damaged by one larva. The injury gives the pods a very unsightly appearance, necessitating hand culling prior to marketing the crop. In cases where wormy pods are not culled out prior to shipment, the worms present in pods enclosed in the hampers may leave these pods and enter worm-free pods, thus adding to the damage while in transit. In many instances, also, rot-producing organisms gain entrance through the holes made by the worms and, developing inside the pod, cause it to decay, thereby adding to the severity of the injury. When the worm attacks young pods it causes many of those injured to drop.

LAY-OUT AND METHOD OF SAMPLING

The experiments reported on herein were conducted on the Fordhook variety of bush lima beans (*Phaseolus lunatus macrocarpus*) in the vicinity of Eastville, Va., the plots being in the same field each season. During both seasons several acres of field corn was on one side of the lima bean field, making an ideal situation for the development of a corn earworm infestation, as the moths developing in the corn contributed to the infestation on beans.

Results of the experiments are based on records of the injured and of the uninjured pods at the time of the regular picking of the crop. Pods were considered wormy if a worm hole had been made through the pod wall, as such pods are culled out and sold separately by growers. The plants in one of the two center rows of each plot were counted and the beans on all plants in the row were examined and counted, records being made of the wormy, or injured, and the uninjured pods. This involved the examination of 6,999 pods from the experiment of 1935 and 28,553 from that of 1936. In 1937, 38,856, and in 1938, 11,122, were examined.

METHOD OF APPLICATION

The sprays were applied with knapsack sprayers capable of maintaining a constant pressure of 150 pounds. Dusts were applied with bellows-type knapsack dusters. The beans were treated from each side of the row, the top of the foliage being covered in one direction and the under surface in the other, in order that all parts of the plants might be thoroughly covered and that the treatments might be effective simultaneously for control of the Mexican bean beetle (*Epilachna varivestis* Muls.). Fortunately, however, from the standpoint of the evaluation of the results of the experiments, very few Mexican bean beetles appeared in the plots; injury by this insect was therefore not a factor in the results of any of the experiments reported herein.

PROCEDURE AND RESULTS IN FIELD-CONTROL EXPERIMENTS

EXPERIMENT 1

In outlining an experiment for control of the corn earworm on Fordhook lima beans in 1935 it was recognized that there would usually be injury by the Mexican bean beetle on this crop along with that caused by the corn earworm. It was therefore decided to test materials which had previously proved to be relatively safe on bean foliage and toxic to the Mexican bean beetle.

Plots containing four rows 44 feet long and 2½ feet apart were used. Each treated plot was duplicated in the field and eight untreated plots were situated in various sections of the field.

Treatments were applied on September 9, 16, and 26, and October 4 and 15. At the time of the first treatment the beans were blooming and setting small pods, the largest being about three-fourths of an inch long. Observations made at this time showed that only a few corn earworm eggs and small larvae were present on the plants, the majority of these being on the upper surfaces of the leaves. By the time of the third treatment eggs and larvae were numerous on the upper surfaces of the leaves, and worms were observed feeding on and in the pods. At the time of the fourth treatment larvae were not nearly so numerous, and when the fifth treatment was given very

few larvae were seen, the majority of these being almost full grown and feeding mainly on the pods. While these observations were being made many small pods showing worm injury were seen on the ground beneath the plants, indicating that worm injury was causing severe shedding of the young pods. The beans were picked on October 24 and November 5.

EXPERIMENT 2

The procedure with reference to the experiment of 1936 was essentially the same as during the preceding season, except that more replications were provided for each treatment and a few additional insecticides were tested.

Each plot in the experiment contained four rows 44 feet long and 2½ feet apart. The plots for the various treatments were randomized in four blocks, the plot for each kind of treatment occurring once within each block. Thus each plot in the experiment was replicated four times. Each block also contained one untreated plot.

Treatments were given on September 3, 10, and 24-25. At the time of the first treatment the plants were blooming and setting small pods. Field counts were made at this time relative to the status of the corn earworm infestation in the plots. No eggs or larvae were found in an examination of 100 plants in various sections of the field. Several wormy pods were found, however, indicating that larvae were present on the plants. Also, several moths were seen flying about in the field, these being the first moths observed in this bean field. When the second treatment was given, eggs and larvae were numerous on the plants, and at the time of the third treatment eggs were scarce although larvae and wormy pods were numerous. The beans were picked on October 6-7, and 28.

In view of the fact that the moths which produce the infestation on beans develop in adjoining cornfields, notes on the stage of development of the corn are of value with reference to the timing of treatments for control of the earworm on beans. On August 27 (7 days prior to the first insecticidal treatment) examinations showed that the silks on 87 percent of the corn ears in the adjoining field had dried out, larval exit holes being seen on the husks of many of the ears examined, indicating that the majority of the larvae were entering the soil for pupation. At the time of the first insecticidal treatment (September 3) the silks were dry on 98 percent of the ears examined and the majority of the ears contained larval exit holes. It has previously been stated that the first moths were observed in the experimental plots of lima beans on September 3. From the observations noted above, these moths had apparently just recently emerged in the adjoining cornfield.

DISCUSSION OF RESULTS

The results of the experiments are presented in table 1 and figure 2 for 1935 and in table 2 for 1936. Since the plants in all plots were counted, the calculations were made on a per-plant basis. It was recognized early in the progress of the 1935 experiment that in considering the degree of control from the various treatments, the percent control as determined by the average decrease in the number of wormy pods per plant under those from the untreated plots would not be a true index of control owing to injury and consequent shed-

ding of wormy pods on both the treated and untreated plots. It therefore appeared that the increases in the average number of pods produced per plant over those from the untreated plots would have to be considered along with the former in order properly to evaluate the results. This fact is borne out by the results of the experiments (tables 1 and 2).

TABLE 1.—Results of treatments for control of the corn earworm on Fordhook lima beans, showing percentage of control and increases in the number of pods produced owing to treatment, experiment 1, 1935

Plot No.	Insecticide used (dusts, proportions of materials; sprays, pounds of material in 50 gallons of water)	Average rate applied per acre	Plants per plot	Average number of wormy pods per plant	Average increase (+) or decrease (−) over check in wormy pods per plant		Average number of pods produced per plant	Average increase (+) or decrease (−) over check in pods produced per plant	
					Number	Percent		Number	Percent
101	Barium fluosilicate, ¹ undiluted	Pounds 24	Number 34	0.500			9.088		
131	do	25	34	.088			10.706		
	Average	24	34	.294	−0.645	−68.69	9.897	+4.991	+101.73
111	Barium fluosilicate, ¹ 80 parts to 20 parts wheat flour	34	43	.256			8.930		
121	do	36	35	.371			9.000		
	Average	35	39	.313	−.626	−66.67	8.965	+4.059	+82.73
109	Cryolite, ² 60 parts to 40 parts talc	20	39	.538			12.333		
123	do	20	38	.421			7.026		
	Average	20	38	.479	−.460	−48.99	9.679	+4.773	+97.29
107	Derris ³ —talc (0.75 percent rotenone)	23	31	.710			3.839		
125	do	20	29	1.276			5.069		
	Average	21	30	.993	+ .054	+5.75	4.454	−.452	−9.21
115	Derris ³ —talc (1 percent rotenone)	23	48	.667			4.250		
117	do	21	32	1.594			6.062		
	Average	22	40	1.130	+ .191	+20.34	5.156	+ .250	+5.09
116	Barium fluosilicate, ¹ 5 pounds	Gallons 95-100	34	.912			4.265		
130	do	95-100	38	.868			4.895		
	Average		36	.890	−.049	−5.22	4.580	−.326	−6.64
108	Cryolite, ² 3 pounds	95-100	42	.500			8.905		
114	do	95-100	39	.385			9.102		
	Average		40	.442	−.497	−52.93	9.003	+4.097	+83.51
106	Derris root powder ³ (0.025 percent rotenone) ⁴	95-100	38	.895			4.710		
124	do	95-100	30	1.433			4.733		
	Average		34	1.164	+ .225	+23.96	4.721	−.185	−3.77
112	Cube root powder ⁵ (0.025 percent rotenone) ⁶	95-100	43	.837			3.906		
122	do	95-100	35	1.028			7.057		
	Average		39	.932	−.007	−.74	5.481	+ .575	+11.72

¹ Commercial mixture, 72-percent barium fluosilicate.

² Commercial synthetic material.

³ Rotenone content of derris 4.6 percent. Total extractives (carbon tetrachloride method) 16.5 percent.

⁴ Equivalent to 2.5 pounds of derris of 4-percent rotenone content in 50 gallons of water.

⁵ Rotenone content of cube 5.2 percent. Total extractives (carbon tetrachloride method) 17.4 percent.

⁶ Equivalent to 2.5 pounds of cube of 4-percent rotenone content in 50 gallons of water.

TABLE 1.—*Results of treatments for control of the corn earworm on Fordhook lima beans, showing percentage of control and increases in the number of pods produced owing to treatment, experiment 1, 1935—Continued*

Plot No.	Insecticide used (dusts, proportions of materials; sprays, pounds of material in 50 gallons of water)	Average rate applied per acre	Plants per plot	Average number of wormy pods per plant	Average increase (+) or decrease (–) over check in wormy pods per plant		Average number of pods produced per plant	Average increase (+) or decrease (–) over check in pods produced per plant	
					Number	Percent		Number	Percent
103	Untreated.....	Pounds	Number	0.788			3.848		
104	do.....		36	1.444			5.305		
110	do.....		39	.487			6.461		
113	do.....		37	.946			6.594		
119	do.....		41	.976			3.902		
120	do.....		39	.974			2.615		
126	do.....		38	1.289			7.947		
129	do.....		38	.605			2.579		
	Average.....		38	.939			4.906		

TABLE 2.—*Results of treatments for control of the corn earworm on Fordhook lima beans, showing percentage of control and increases in the number of pods produced owing to treatment, experiment 2, 1936*

Block	Insecticide used (dusts, proportions of materials; sprays, pounds of material in 50 gallons of water)	Average rate applied per acre	Plants per plot	Average number of wormy pods per plant ¹	Average increase (+) or decrease (–) over check in wormy pods per plant		Average number of pods produced per plant ²	Average increase (+) or decrease (–) over check in pods produced per plant	
					Number	Percent		Number	Percent
A	Cryolite, ³ undiluted.....	Pounds	Number	0.425			11.825		
B	do.....	8	40	.465			12.465		
C	do.....	10	43	.146			13.854		
D	do.....	13	48	.136			16.795		
	Average.....	10	44	.293	–0.451	–60.62	13.735	+3.884	+39.42
A	Cryolite, ³ 60 parts to 40 parts talc.....	21	42	.238			12.881		
B	do.....	19	39	.436			10.641		
C	do.....	21	43	.372			13.744		
D	do.....	19	40	.150			12.900		
	Average.....	20	41	.299	–.445	–59.81	12.541	+2.690	+27.31
A	Cryolite, ³ 60 parts to 40 parts sulphur.....	25	47	.276			11.276		
B	do.....	16	43	.279			9.721		
C	do.....	21	38	.500			15.657		
D	do.....	15	42	.309			10.095		
	Average.....	19	42	.341	–.403	–54.17	11.687	+1.836	+18.64
A	Cryolite, ⁴ 60 parts to 40 parts talc.....	15	42	.809			9.857		
B	do.....	15	40	.575			13.025		
C	do.....	16	47	.447			13.000		
D	do.....	22	40	.250			13.025		
	Average.....	17	42	.520	–.224	–30.11	12.227	+2.376	+24.12

¹ A difference of 0.339 wormy pods per plant between any 2 means is required for significance.² A difference of 2.84 pods produced per plant between any 2 means is required for significance.³ Commercial synthetic material. Fluorine content 48.9 percent, equivalent content of cryolite (sodium fluoaluminate) 90.1 percent. Material occupies about 40 cubic inches to the pound.⁴ Newly introduced brand of commercial synthetic material. Fluorine content 48.9 percent, equivalent content of cryolite (sodium fluoaluminate) 90.1 percent. Material occupies from 85 to 100 cubic inches to the pound.

TABLE 2.—Results of treatments for control of the corn earworm on Fordhook lima beans, showing percentage of control and increases in the number of pods produced owing to treatment, experiment 2, 1936—Continued

Block	Insecticide used (dusts, proportions of materials; sprays, pounds of materials in 50 gallons of water)	Average rate applied per acre	Plants per plot	Average number of wormy pods per plant	Average increase (+) or decrease (−) over check in wormy pods per plant		Average number pods produced per plant	Average increase (+) or decrease (−) over check in pods produced per plant	
					Number	Percent		Number	Percent
A	Hydrated lime, undiluted.....	21	37	0.432	-----	-----	8.785	-----	-----
B	do.....	17	35	.800	-----	-----	9.600	-----	-----
C	do.....	16	37	.892	-----	-----	11.027	-----	-----
D	do.....	23	39	.743	-----	-----	8.051	-----	-----
	Average.....	19	37	.717	-.027	-3.63	9.366	-.485	-4.92
A	Derris, ³ 15 percent pyrethrum, sulphur (0.75 percent rotenone).....	19	43	.697	-----	-----	10.581	-----	-----
B	do.....	23	41	.463	-----	-----	8.390	-----	-----
C	do.....	17	39	1.128	-----	-----	9.102	-----	-----
D	do.....	21	43	.939	-----	-----	9.046	-----	-----
	Average.....	20	41	.807	+ .063	+8.46	9.280	-.571	-5.79
A	2 percent nicotine in bentonite-sulphur.....	15	40	1.000	-----	-----	12.450	-----	-----
B	do.....	23	41	.658	-----	-----	8.512	-----	-----
C	do.....	23	40	.975	-----	-----	14.350	-----	-----
D	do.....	21	40	.800	-----	-----	9.175	-----	-----
	Average.....	20	40	.858	+ .114	+15.32	11.122	+1.271	+12.90
A	Pyrethrum, ⁶ 25 parts to 75 parts sulphur.....	29	41	.731	-----	-----	11.122	-----	-----
B	do.....	23	37	.702	-----	-----	5.297	-----	-----
C	do.....	27	44	1.045	-----	-----	13.455	-----	-----
D	do.....	25	40	.925	-----	-----	9.200	-----	-----
	Average.....	26	40	.851	+ .107	+14.38	9.768	-.083	-.84
A	Derris ⁶ -sulphur (1 percent rotenone).....	23	37	.917	-----	-----	8.810	-----	-----
B	do.....	21	41	1.097	-----	-----	10.902	-----	-----
C	do.....	23	41	.658	-----	-----	9.707	-----	-----
D	do.....	19	44	1.273	-----	-----	10.068	-----	-----
	Average.....	21	41	.986	+ .242	+32.53	9.872	+ .021	+ .21
A	Cube ⁷ -sulphur (1 percent rotenone).....	17	40	.650	-----	-----	11.675	-----	-----
B	do.....	23	40	1.050	-----	-----	9.200	-----	-----
C	do.....	21	47	.936	-----	-----	11.830	-----	-----
D	do.....	21	42	1.357	-----	-----	9.309	-----	-----
	Average.....	20	42	.998	+ .254	+34.14	10.503	+ .652	+6.62
A	Cryolite, ³ 3 pounds.....	Gallons 95-100	44	.432	-----	-----	8.340	-----	-----
B	do.....	95-100	43	.605	-----	-----	6.442	-----	-----
C	do.....	95-100	44	.386	-----	-----	15.023	-----	-----
D	do.....	95-100	45	.311	-----	-----	15.890	-----	-----
	Average.....	-----	44	.433	-.311	-41.80	11.401	+1.550	+15.73
A	Phenothiazine (thiodiphenylamine), ⁸ 3 pounds.....	95-100	42	.285	-----	-----	9.524	-----	-----
B	do.....	95-100	44	.545	-----	-----	9.159	-----	-----
C	do.....	95-100	44	.636	-----	-----	13.169	-----	-----
D	do.....	95-100	34	.470	-----	-----	11.058	-----	-----
	Average.....	-----	41	.484	-.260	-34.95	10.725	+ .874	+8.87

³ Commercial synthetic material. Fluorine content 48.9 percent, equivalent content of cryolite (sodium fluoaluminate) 99.1 percent. Material occupies about 40 cubic inches to the pound.

⁶ Rotenone content of derris 4.7 percent, total extractives (carbon tetrachloride method) 16.8 percent.

⁷ Analysis showed 0.40 percent pyrethrin I and 0.63 percent pyrethrin II.

⁸ Rotenone content of cube 5.1 percent, total extractives (carbon tetrachloride method) 16.1 percent.

⁹ Commercial synthetic organic sulphur compound with the formula C₁₂H₉NS.

TABLE 2.—Results of treatments for control of the corn earworm on Fordhook lima beans, showing percentage of control and increases in the number of pods produced owing to treatment, experiment 2, 1936—Continued

Block	Insecticide used (dusts, proportions of materials: sprays, pounds of materials in 50 gallons of water)	Average rate applied per acre	Plants per plot	Average number of wormy pods per plant	Average increase (+) or decrease (−) over check in wormy pods per plant		Average number pods produced per plant	Average increase (+) or decrease (−) over check in pods produced per plant	
					Number	Percent		Number	Percent
A	Cuprous cyanide, 2 pounds..	Pounds 95-100	Number 43	0.605	-----	-----	11.279	-----	-----
B	do.....	95-100	47	.680	-----	-----	6.021	-----	-----
C	do.....	95-100	41	1.219	-----	-----	11.609	-----	-----
D	do.....	95-100	47	.617	-----	-----	9.468	-----	-----
	Average.....		44	.780	+ .036	+4.84	9.594	− .257	−2.61
A	Hydrated lime, 10 pounds..	95-100	45	.822	-----	-----	6.622	-----	-----
B	do.....	95-100	40	.900	-----	-----	11.000	-----	-----
C	do.....	95-100	41	.415	-----	-----	9.146	-----	-----
D	do.....	95-100	42	1.142	-----	-----	9.357	-----	-----
	Average.....		42	.820	+ .076	+10.22	9.031	− .820	−8.32
A	Untreated.....		47	.657	-----	-----	9.620	-----	-----
B	do.....		40	.680	-----	-----	9.220	-----	-----
C	do.....		41	.758	-----	-----	11.582	-----	-----
D	do.....		44	.881	-----	-----	8.981	-----	-----
	Average.....		43	.744	-----	-----	9.851	-----	-----

Table 1 shows the results of experiment 1 conducted in 1935. In each instance the average results of duplicate treated plots are shown, these being followed by the results of the untreated plots. Dusts and sprays are listed separately in the order of their effectiveness for control of the insect.

The data in table 1 show that synthetic cryolite 60 parts with talc 40 parts by weight (fig. 2, *C*), commercial barium fluosilicate either undiluted (fig. 2, *A*), or diluted at the rate of 80 parts by weight with 20 parts of wheat flour, gave the best corn earworm control as indicated by the reductions in the number of wormy pods per plant and by the increases in the average number of pods produced per plant over those from the untreated plots (fig. 2, *B*). No control was obtained with derris-talc dusts with rotenone contents of 0.75 or 1.0 percent. Of the sprays used in the experiment, synthetic cryolite applied at the rate of 3 pounds in 50 gallons of water gave the best control, the results being far superior to that obtained with barium fluosilicate used at the rate of 5 pounds in 50 gallons of water. It will also be noted that unsatisfactory results were obtained with water suspensions of ground derris or of cube root at dosages equivalent to 2½ pounds of derris or cube of 4-percent rotenone content in 50 gallons of water (rotenone content of sprays 0.025 percent).

No noticeable insecticidal injury to the plants resulted from the application of any of the materials used in experiment 1.

Table 2 shows the results of experiment 2 conducted in 1936. In each instance the average results of quadruplicate treated plots are shown, these being followed by the results of the untreated plots. Dusts and sprays are listed separately in the order of their effectiveness for control of the insect, each plot replicate being listed according to the block in which it occurred.

Tests with barium fluosilicate were omitted in experiment 2 owing to the double hazard of harmful insecticidal residues incurred by the presence of barium and fluorine. This material, moreover, is not so effective as cryolite for the control of the Mexican bean beetle, which usually occurs in association with the corn earworm on this crop.

The data in table 2 with reference to the average number of wormy pods per plant, and the average number of pods produced per plant, were treated statistically by Paterson's method of randomized block comparisons.² In the case of the former (average number of wormy pods per plant), the analysis showed that a difference of 0.339 in the means of the different treated plots from the mean of the untreated plots was required for significance. This difference occurred only between the untreated plots and the plots treated with undiluted cryo-

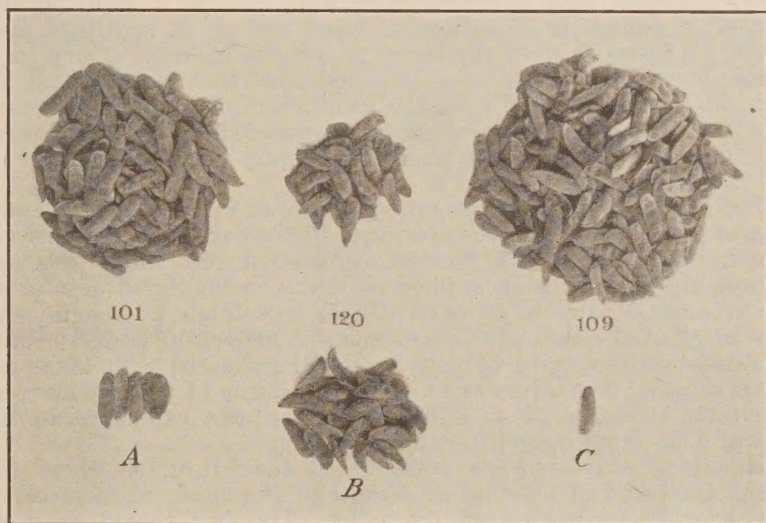


FIGURE 2.—Comparative yields of Fordhook lima beans from treated and untreated plots at the time of the first picking of experiment 1. (This illustrates an extreme case of control rather than an average case.) A, Treated with barium fluosilicate, undiluted; B, untreated; C, treated with cryolite-talc dust. Wormy pods below and uninjured pods above. Note the degree of control shown by the reduction in the number of wormy pods on treated compared with untreated plots, and by the increases in the total number of pods produced owing to treatment. Owing to the extra hazard in the use of barium fluosilicate on account of harmful residues, the Department does not recommend the use of this material. (The figures in the photograph refer to the plot numbers.)

lite, cryolite-talc, and cryolite-sulphur, on which the average decreases in wormy pods per plant were 60.6, 59.8, and 54.2 percent, respectively. In the case of the latter (average number of pods produced per plant), a difference of 2.84 in the means of the different treated plots from the mean of the untreated plots was required for significance. This difference occurred only on the plots treated with undiluted cryolite dust, on which the average increase over the untreated plots was 39.4 percent. It will be seen from table 2 that the results with cryolite dusts and sprays corroborate those shown in table 1.

Table 2 shows, further, that derris-sulphur (1.0 percent of rotenone), cube-sulphur (1.0 percent of rotenone), derris-15 percent

² PATERSON, D. D. EXPERIMENTATION AND APPLIED STATISTICS FOR THE PRACTICAL AGRICULTURIST. Trop. Agr. 10: 267-276; 303-311, 346-351. 1933.

pyrethrum-sulphur (0.75 percent of rotenone), pyrethrum 25-sulphur 75, and 2-percent nicotine in bentonite-sulphur were not effective in controlling the pest. Results with derris dust treatments confirmed the results secured with these materials in experiment 1 (table 1).

Phenothiazine (thiodiphenylamine) used as a spray at the rate of 3 pounds in 50 gallons of water (table 2) failed to show a significant reduction in worm injury.

Cuprous cyanide used at the rate of 2 pounds in 50 gallons of water (table 2) was not effective for control of the insect and caused slight insecticidal injury to the foliage shortly after the first treatment. The injury apparently was not permanent, however, as there was no noticeable injury on plots treated with this material at the conclusion of the experiment.

Plots treated with hydrated lime, used both as a spray at the rate of 10 pounds in 50 gallons of water and as an undiluted dust (table 2), failed to show significant reductions in worm injury compared with untreated plots. This indicates that no repellent or larvicidal action resulted from the application of this inert material.

With the exception of the slight injury noted above (on the cuprous cyanide plots), no noticeable insecticidal injury resulted from any of the treatments in experiment 2.

The results of the experiments (tables 1 and 2) show that in addition to giving a high degree of control of the corn earworm on pods remaining on the plants at harvest, applications of cryolite dusts and sprays, the former being applied either as an undiluted dust or at the rate of 60 parts to 40 parts of talc or sulphur by weight, and the latter at the rate of 3 pounds in 50 gallons of water, caused increases in the number of pods produced compared with untreated plots, showing that injury and resultant shedding of young pods were prevented. Results of an additional experiment conducted in the fall of 1937 further confirmed these findings.

Results of additional tests conducted in the fall of 1938 show that a bait composed of 1 pound of cryolite to 25 pounds of cornmeal is also effective for control of this insect. This bait should prove of considerable value in instances where the grower is not equipped to dust or spray, or in cases where the bean foliage has attained such dense growth that the use of horse-drawn equipment would be impracticable. The bait should be applied at the rate of 50 pounds per acre per application, broadcast evenly over the leaves of the plants at the same time intervals as for dust or spray applications. If the Mexican bean beetle is present in injurious numbers along with the corn earworm, the dust or spray should be used in preference to the bait, as this material is not effective for control of the Mexican bean beetle.

RESULTS OF ANALYSES OF LIMA BEANS FOR FLUORINE RESIDUES

SHELLED AND UNSHELLED FORDHOOK LIMA BEANS

In order to obtain information relative to the quantities of fluorine present upon harvested Fordhook lima beans following treatments with cryolite dusts and sprays (September 3, 10, 24-25) for control of the corn earworm, a large number of samples of shelled and unshelled beans were obtained at the time of the first picking of experiment 2 (October 6-7), and submitted to the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quar-

antine for analysis for fluorine residues. The results of the analyses are given in table 3.

TABLE 3.—Results of analyses of shelled and unshelled Fordhook lima beans for fluorine residues ¹

Description of sample	Dilution	Fluorine per pound of beans ²
		<i>Grain</i>
Shelled beans treated with cryolite ³	3 pounds to 50 gallons water.....	Less than 0.012.
	do.....	Less than 0.009.
	Undiluted.....	Less than 0.009.
	do.....	Less than 0.009.
	60 parts to 40 parts talc.....	Less than 0.008.
	do.....	Less than 0.009.
Shelled beans treated with cryolite ⁴	60 parts to 40 parts sulphur.....	Less than 0.009.
	do.....	Less than 0.009.
	60 parts to 40 parts talc.....	Less than 0.009.
Shelled beans untreated	do.....	Less than 0.010.
	Untreated.....	Less than 0.009.
Unshelled beans treated with cryolite ²	do.....	Less than 0.009.
	3 pounds to 50 gallons water.....	0.014.
	do.....	0.009.
	do.....	0.009.
	do.....	0.014.
	do.....	0.014.
	do.....	0.009.
	do.....	0.014.
	do.....	0.014.
	Undiluted.....	0.014.
	do.....	0.009.
	do.....	0.009.
	do.....	0.009.
	do.....	0.024.
	do.....	0.024.
	do.....	0.024.
	do.....	0.024.
	do.....	0.024.
	60 parts to 40 parts talc.....	0.024.
	do.....	0.019.
Unshelled beans treated with cryolite ⁴	do.....	0.014.
	do.....	0.019.
	do.....	0.019.
	do.....	0.019.
	do.....	0.024.
	do.....	0.024.
	do.....	0.024.
	60 parts to 40 parts sulphur.....	0.028.
	do.....	0.024.
	do.....	0.024.
	do.....	0.029.
	do.....	0.014.
	do.....	0.014.
	do.....	0.024.
Unshelled beans untreated	do.....	0.024.
	60 parts to 40 parts talc.....	0.004.
	do.....	0.024.
	do.....	0.009.
	do.....	0.014.
	do.....	0.019.
Unshelled beans treated with cryolite ⁴	do.....	0.019.
	do.....	0.019.
	do.....	0.009.
	do.....	0.009.
Unshelled beans untreated	Untreated.....	Less than 0.004.
	do.....	Less than 0.004.

¹ Treatments applied on September 3, 10, and 24-25; beans picked October 6-7.

² The Division of Insecticide Investigations of the Bureau states that owing to the inability to determine amounts of fluorine smaller than 0.005 mg, the results on the shelled beans and check unshelled beans are reported as less than the figures shown.

³ Commercial synthetic material. Fluorine content 48.9 percent, equivalent content of cryolite (sodium fluoaluminate) 90.1 percent. Material occupies about 40 cubic inches to the pound.

⁴ Newly introduced brand of commercial synthetic material. Fluorine content 48.9 percent, equivalent content of cryolite (sodium fluoaluminate) 90.1 percent. Material occupies from 85 to 100 cubic inches to the pound.

Table 3 shows that in the cases of the shelled beans the grains of fluorine per pound is in most instances well below the tolerance which has been established for fluorine on fruits (0.01 grain fluorine per pound), while in the cases of the unshelled beans the grains of fluorine per pound in the majority of instances is well above this tolerance.

The results indicate that cryolite dusts and sprays may be applied for control of the corn earworm on lima beans without danger of harmful fluorine residues on the edible portions provided the beans are shelled before human consumption.

In the fall of 1937 additional analyses were made of a large number of samples of shelled and unshelled lima beans. The results corroborate those of 1936.

CANNED HENDERSON BUSH LIMA BEANS

Since the corn earworm also attacks the Henderson bush variety of lima bean which is grown extensively for canning, samples of this variety were likewise submitted to the Division of Insecticide Investigations for analysis for fluorine residues on the canned product. The field from which the samples were obtained was treated on September 10 and 25 with synthetic cryolite 60 parts and talc 40 parts, by weight. At the time of the first treatment the beans were blooming and setting pods. The second treatment was given 12 days prior to canning. On October 7 the vines were cut and the beans run through the viner and canned in accordance with the regular canning procedure for this crop. The results of the analyses are given in table 4.

TABLE 4.—*Results of analyses of canned and shelled Henderson bush lima beans for fluorine residues*

Sample	Treatment	Dilution	Description of sample	Fluorine per pound of shelled beans ¹
A -----	Cryolite ² -----	60 parts to 40 parts talc.---	Canned beans.---	<i>Grain</i> Less than 0.004.
B -----	...do ³ -----	...do -----	Shelled beans ³ -----	0.013.
C -----	Untreated -----	-----	Canned beans.---	Less than 0.003.

¹ The Insecticide Division states that owing to the inability to determine amounts of fluorine smaller than 0.005 mg. the results on samples A and C are reported as less than the figures shown.

² Commercial synthetic material. Fluorine content 48.9 percent, equivalent content of cryolite (sodium fluoaluminate) 90.1 percent. Material occupies about 40 cubic inches to the pound.

³ Shelled beans just as they come from the viner without washing or grading.

Table 4 shows that the grains of fluorine per pound in canned lima beans (sample A), treated as described above and run through the regular washing process practiced for this crop, is well below the tolerance that has been established for fluorine on fruits. In the case of sample B, however (shelled beans just as they come from the viner without washing or grading), the grains of fluorine per pound slightly exceeds this tolerance. This indicates that the ordinary washing process in the canning of this crop effectively removes harmful fluorine residues deposited through outside agencies. It is surprising to note that the shelled beans in sample B showed such a small quantity of fluorine. In view of the fact that this sample was taken under the conditions described above, it was expected that it would collect large amounts of fluorine during its passage through the viner.

CONTROL RECOMMENDATIONS

The recommendations offered are based on the results of 4 years' experimental work of which the results of the 1935 and 1936 experiments are discussed in detail in this circular. These experiments show that corn earworm damage on lima beans can be appreciably reduced by the use of cryolite.

In general, cryolite dust mixtures, made according to either of the following formulas, have given better results than sprays in corn earworm control:

Cryolite, undiluted.....	10 to 12 pounds per acre per application.
or	
Cryolite, 60 pounds.....	} 20 to 25 pounds per acre per application.
Talc or sulphur, 40 pounds.....	

If the use of a spray is desired, the material should be applied according to the following formula:

	For large areas	For small areas
Cryolite.....	3 pounds	3 ounces (9 level tablespoonfuls).
Water.....	50 gallons	3 gallons.

Sulphur is recommended in preference to talc as a diluent for cryolite in instances where the potato leafhopper (*Empoasca fabae* (Harr.)) or the common red spider (*Tetranychus telarius* (L.)) is present along with the corn earworm. In the case of the spray, wettable sulphur may be added to the cryolite at the rate of 2 pounds to 50 gallons of water.

A bait composed of 1 pound of cryolite to 25 pounds of cornmeal, broadcast evenly over the leaves of the plants at the same time intervals as for dust or spray applications, is also effective for the control of this insect on lima beans.

Treatments should be begun when the majority of the silks on ears of field corn in the vicinity of late plantings of lima beans have dried out, or not later than such time as the lima bean plants under observation are in full bloom, unless earlier treatments are required for control of the Mexican bean beetle.

As corn earworm moths are continually emerging and depositing eggs which are not affected by the treatment, and since new untreated foliage is constantly developing, treatments should be repeated at weekly or 10-day intervals. Three or four treatments are usually necessary, depending on the abundance of the insect. In order to avoid the danger of harmful fluorine residues on the edible portions of the market product, treatments should be discontinued 2 weeks prior to harvest. Dusts should be applied when little or no wind is blowing. If rains occur within 48 hours after a treatment is given, the application should be repeated as soon as conditions will permit.

In order to secure thorough coverage of all parts of the plants, and to make the treatments effective simultaneously for control of the Mexican bean beetle, the insecticide should be directed to both the upper and lower surfaces of the leaves. This may be accomplished by making minor adjustments to the nozzles of dusters and sprayers equipped for control of the Mexican bean beetle.⁵

SUMMARY

Corn earworm larvae often cause severe damage to lima bean pods by boring through the pod wall and devouring the contents of the pod. The injury thus caused necessitates hand culling of the damaged pods

⁵ HOWARD, NEALE F., BRANNON, LOYD W., and MASON, HORATIO C. THE MEXICAN BEAN BEETLE IN THE EAST AND ITS CONTROL. U. S. Dept. Agr. Farmers' Bull. 1624 (rev.), 21 pp., illus. 1936.

prior to marketing the crop. Injury to young pods causes many of them to shed.

Investigations show that corn earworm damage may be appreciably reduced by the application of cryolite dusts or sprays, the former being applied either as an undiluted dust or at the rate of 60 parts to 40 parts of talc or sulphur by weight, and the latter at the rate of 3 pounds in 50 gallons of water. It was found that in addition to giving a high degree of control of the insect on pods remaining on the plants at harvest, applications of these materials caused increases in the number of pods produced compared with the untreated plots, showing that injury and resultant shedding of young or immature pods was prevented.

In order to secure thorough coverage of all parts of the plants, the insecticide should be directed to both the upper and lower surfaces of the leaves.

A bait composed of 1 pound of cryolite to 25 pounds of cornmeal, broadcast evenly over the leaves of the plants at the same time intervals as for dust or spray applications, is also effective for control of this insect on lima beans.

Treatments should be begun when the majority of the silks on ears of field corn in the vicinity of late plantings of lima beans have dried out, or not later than such time as the lima bean plants under observation are in full bloom.

Three or four treatments are usually necessary, depending on the abundance of the insect. In order to avoid the danger of harmful fluorine residues on the edible portions of the market product, treatments should be discontinued 2 weeks prior to harvest. *See p. 10.*

The results of analyses of samples of shelled and unshelled Fordhook lima beans for fluorine residues showed that in most cases the grains of fluorine per pound with reference to the shelled beans was well below the tolerance established for fluorine on fruits, while the grains of fluorine per pound on the unshelled beans (that is, where pods and beans were analyzed) was in most instances well above this tolerance.

The results of analyses of samples of canned lima beans following field treatments with cryolite-talc dust showed that the grains of fluorine per pound was well below the tolerance established for fluorine on fruits, indicating that the ordinary washing process in the commercial canning of the crop effectively removes harmful fluorine residues deposited through outside agencies.

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<i>Weather Bureau</i> -----	F. W. REICHELDERFER, <i>Chief.</i>

This circular is a contribution from

<i>Bureau of Entomology and Plant Quarantine</i> -----	LEE A. STRONG, <i>Chief.</i>
<i>Division of Truck Crop and Garden Insect Investigations</i> -----	W. H. WHITE, <i>Principal Entomologist, in Charge.</i>

